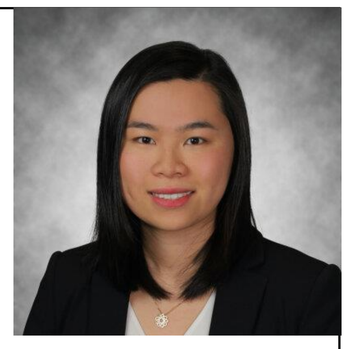
Senior Project – Mechanical Engineering 2020

The Design of Transformable Origami-inspired Furniture



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Introduction

As more and more people are living in metropolitan areas, housing becomes less affordable and the living spaces more confined. However, less living space does not necessarily mean one needs to sacrifice a table to eat or a chair to sit on. The need to be innovative on the traditional design of furniture is urgent in this matter. Origami is the ancient art of paper folding, and its traditional form usually involves only straight folds on a planar piece of paper without tearing, cutting or gluing. Once folded, the origami constitutes a developable surface that can be unfolded as a flat plane [1]. Though the traditional purpose of origami is rather recreational and artistic, with suitable origami geometry, engineers are able to create self-folding structures with it [2]. For example, NASA scientists have incorporated origami design principles to fit a giant *Starshade* into spaceship to deploy thin sheets to a larger structure, shown in Figure 1[3].

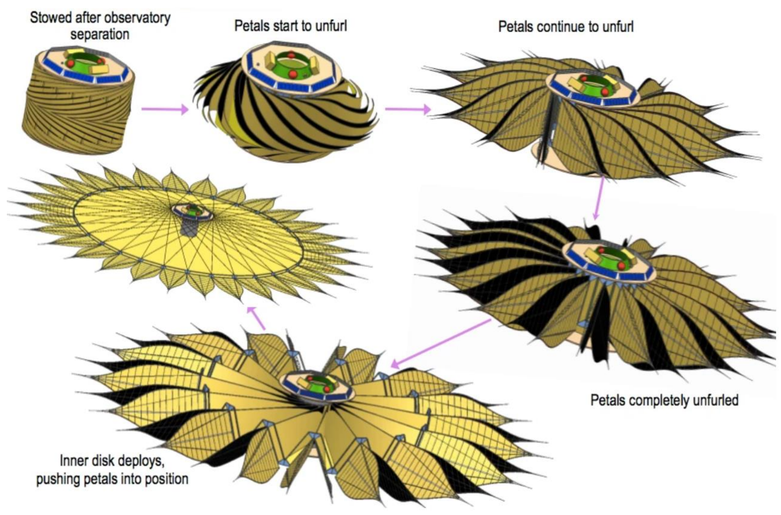

Figure 1. The Deployment Process of *Starshade* [3].

Origami-inspired Chair Design Concept

The vision of the final product is to develop a chair, that will start from a flat sheet for easy storage, and then transform origami-like into an aesthetic and comfortable shape for sitting. The design concept was finalized to incorporate six main pieces with flexible hinges that transforms in a one-degree-of-freedom, easily deployable chair. The sequence of positions that illustrates how the chair geometry is transformed from flat is shown in Figure 2.

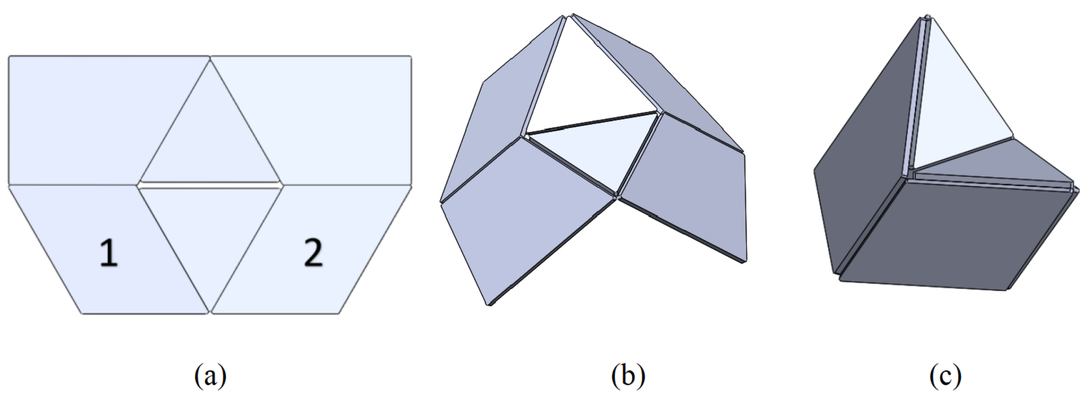

Figure 2. Sequence of the Positions of Origami-Inspired Chair using SolidWorks

Flexible Hinge Design

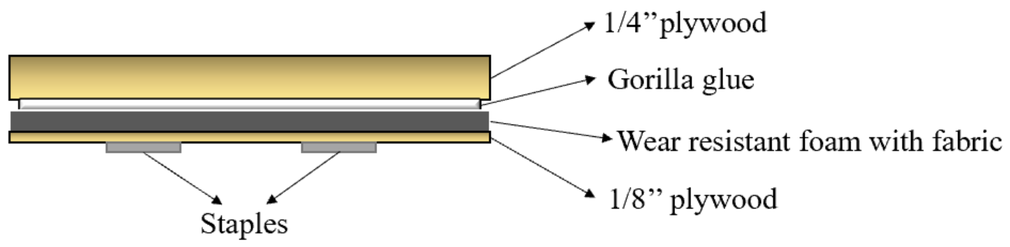

Figure 3. Schematic of the Composite Material

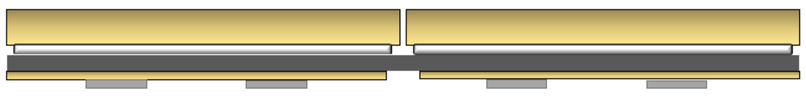

Figure 4. Schematic of the Flexible Hinge

The hinge of the origami chair consists of a customized composite material using structure plywood (top) glued on to foam gum material on the fabric side. The wear resistant foam with fabric is further fastened with another thinner layer of plywood (bottom) stapled to the wear resistant foam (Figure 3). The hinge is created by using one connecting piece of foam fastened on both sides with glue and staples as (Figure 4). A manufactured hinge in bending position is shown in Figure 5.

Figure 5. Manufactured Hinge

Half-scale Chair Prototype

The half-scale chair prototype (Figure 6) was manufactured under $30. A 200lbs load was tested at its sitting position. Due to time restriction, the chair was not tested to failure. Magnets were used to lock the chair in its sitting position.

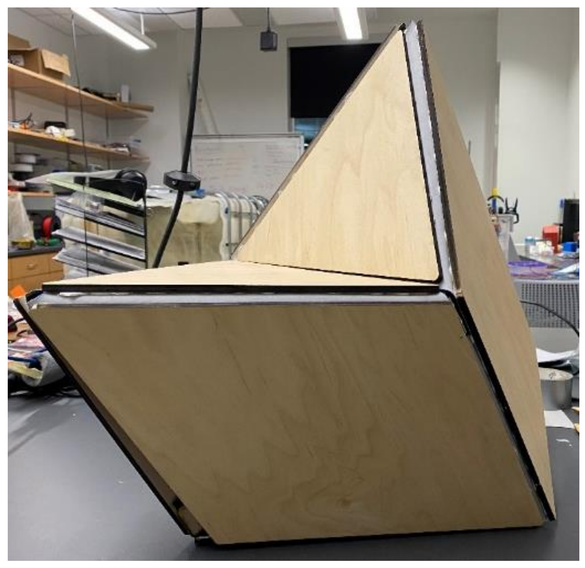

Figure 6. Half-scale Prototype in Sitting Position

Summary

The study of origami engineering is an emerging field and thus unconventional design approaches are required to implement design concepts. In this spirit, SolidWorks Motion was applied to visualize 3D transformation of the chair, and a low cost flexible load-bearing hinge was designed to fulfill the design requirements. The result is an innovative chair design that quickly springs back into a flat shape for ease of storage.

Reference

[1] Dureisseix, David. "An overview of mechanisms and patterns with origami.“a *International Journal of Space Structures* 27.1 (2012): 1-14.

[2]]“Flower Power Starshade Unfurls in Space.” NASA, NASA, https://www.jpl.nasa.gov/video/details.php?id=1284.

[3] Peraza-Hernandez, Edwin A., et al. "Origami-inspired active structures: a synthesis and review." *Smart Materials and Structures* 23.9 (2014): 094001.

Acknowledgements

Professor Keat, Professor Buccinell, Cole Belmont, Professor Dunkin, Paul Tompkins and Rob Harlan, Stan Gorski, Student Research Grant